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ABSTRACT Through experimentation, a continuous wave oxygen-iodine chemical laser was achieved. When the amount of chlorine flow was 50mmol/s, the output power reached 1kW. In conjunction with this, measurements were made of beam divergence angles, investigating the relationships between beam divergence angles and power as well as cavity reflector curvature radii.

KEY WORDS CW chemical oxygen-iodine laser Excited oxygen $O_2(^1\Delta)$ generator Beam divergence

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I INTRODUCTION

Chemical oxygen-iodine lasers (COIL) are, up to the present time, the first chemical lasers to make applications of atomic electron transitions. The laser operating wave length λ is 1.315 microns. It is based on the iodine atom I(2P1/2) -> I(2P3/2) transition.

$$I^{*}(^2P_{1/2}) \rightarrow I(^2P_{3/2}) + h\nu \qquad (1)$$

The energy of iodine atoms in an excited state comes from close resonance energy transfer associated with excited oxygen $O_2(^1\Delta)$

$$O_2(^1\Delta) + I(^2P_{3/2}) \rightarrow I^{*}(^2P_{1/2}) + O_2(^3\Sigma) \qquad (2)$$

However, the production of oxygen $O_2(^1\Delta)$ in an excited state is dependent on chemical reactions associated with chlorine gas and alkaline hydrogen peroxide solutions

$$Cl_2 + H_2O_2 + 2MOH \rightarrow O_2(^1\Delta) + 2H_2O + 2MCl \text{ , } M = K \text{ , } Na \text{ , } Li \qquad (3)$$

The efficiencies associated with this type of reaction are very high. The $O_2(^1\Delta)$ initially obtained is almost 100% concentration. Iodine atoms are obtained by dissociation from iodine molecules.

$$I_2 + nO_2(^1\Delta) \rightarrow 2I + nO_2(^3\Sigma) \text{ , } 3 \leqslant n \leqslant 5 \qquad (4)$$

From the processes above, it is possible to see that this type of laser is realized primarily through chemical reactions. Basically, there is no need for an external energy source. Moreover, efficiency is very high. Experiments have already empirically demonstrated that the highest chemical efficiencies reach 40% [1]. As a result, oxygen-iodine chemical lasers are easy to amplify. It is possible to achieve great powers and great energies.

Another attraction of oxygen-iodine lasers for people is that wave length and beam qualities are good. The operating wave lengths of oxygen-iodine lasers are 1.315 microns. Using silicon fiber transmission, efficiencies are high. The operating

pressures of oxygen-iodine lasers are 133-400Pa. Very low. As a result, beam quality can be very good. Faculae power densities of currently existing laser systems have already achieved 0.3MW/cm2 [2]. At this time, laser handling of materials is already adequate.

The outstanding advantages associated with oxygen-iodine lasers give rise to interest on the part of scientists from various nations. Since McDermott and others [3] successfully demonstrated the first oxygen-iodine laser in 1978, the levels of laser components have undergone very great improvements. Kilowatt level oxygen-iodine lasers have appeared one after the other [4] [5]. In recent years, oxygen-iodine chemical lasers of ten thousand watt level and above have already operated successfully in the U.S. [6].

This article primarily just makes a description of improvements in excited oxygen $O_2(^1\Delta)$ generators as well as beam quality measurements and influencing factors. /390

2 EXPERIMENTAL EQUIPMENT

Continuous wave oxygen-iodine chemical laser equipment is as shown in Fig.1. It primarily includes such parts as excited oxygen $O_2(^1\Delta)$ generators, water vapor traps, iodine steam generators as well as iodine jet tubes, light cavities along with exhaust systems, and so on. Besides light cavity bodies being plexiglass, other large component sections opt for the use of stainless steel materials.

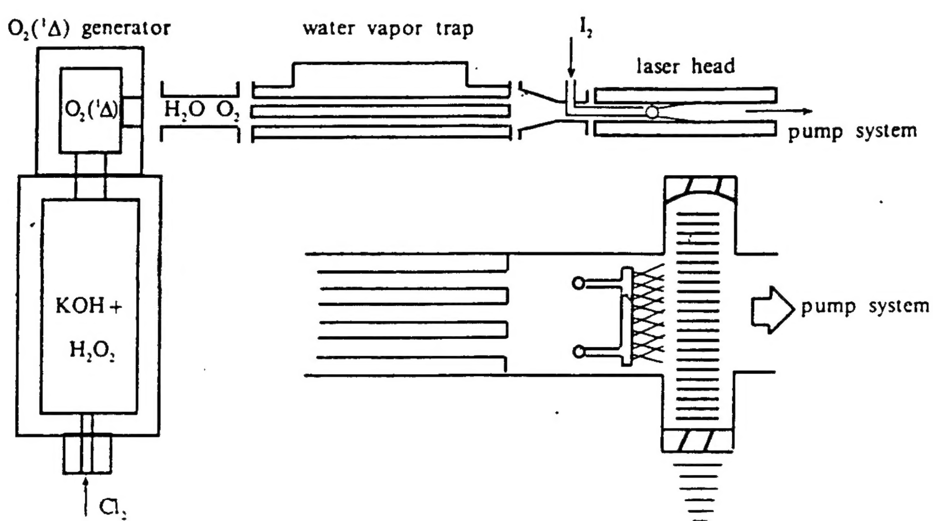

Fig.1 Scheematic of CW chemical oxygen-Iodine laser

Excited oxygen generators are an improved model drum bubble generator. The excited state oxygen generators usually used are drum bubble type generators. Chlorine gas goes through drum bubble devices in reaction solutions and is uniformly distributed inside reaction liquids. Following along with the ascent of gas bubbles, gas bubble volumes get bigger continuously. At the same time, recations go on continuously on the gas-liquid boundary surface between gas bubbles and reaction liquids. Reaction surface area is determined by how many gas bubbles there are. This article opts for the use of improved model drum bubble generators (Fig.2). For detailed structure, see reference [7]. Due to the addition into reaction chambers of polyvinyl chloride rings with approximate total surface areas of 1.3m2, the reaction surface area will be much larger than the usual drum bubble type generator. As a result, generator volumes are very small. Reaction liquids used in experiments are a mixture of 50% concentration H2O2 and 30% concentration KOH. The amount used in each experimental iteration is approximately 1.5L. Chlorine gas flow amounts are 20-30mmol/s. Operating times are 50-60s. /391

Water vapor traps are pipe shell type heat exchangers. The cooling agent is alcohol and dry ice. Operating temperatures are -50°C - -70°C. Experiments clearly show that this type of cooling trap is very effective. Under experimental conditions

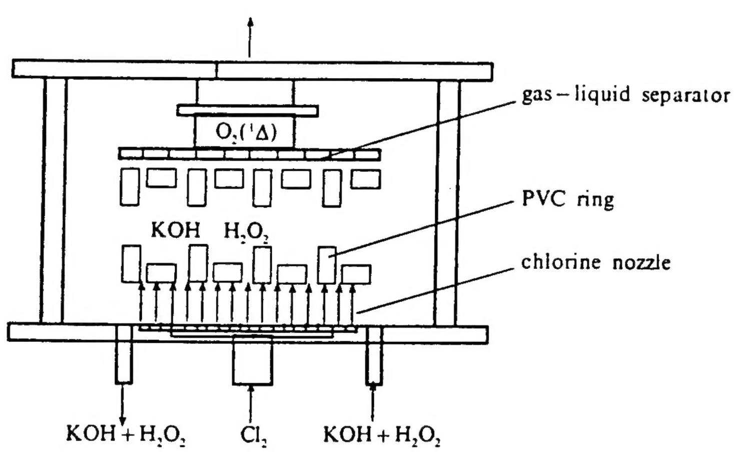

Fig. 2 $O_2(^1\Delta)$ generator

where the amounts of chlorine flow are 30mmol, it is possible to guarantee a water content in gas flows of 2% or less.

Iodine steam generators are made using brass. Interior cavity dimensions are 200mmx40mmx70mm. Iodine steam generator internal cavity temperatures are realized by reliance on adjusting electric heater powers. Normally, generator internal cavity temperatures are 70°C - 80°C. The carrier gas is nitrogen. Iodine jet tubes are stainless steel tubes with internal diameters of 10mm. On the walls of 500mm long tubes are 90 evenly distributed holes with diameters of 0.5mm. The interval between the holes is 5mm. During experiments, in order to prevent iodine steam from condensing on tubing walls and iodine jet tubes, these tubes are all preheated. The directional positioning of iodine gas tu_es in gas flows can be adjusted. The light axis distance is 40-50mm.

In light cavities, iodine concentration measurements opt for the use of argon ion laser (lambda=488.0nm) absorption methods [8]. Under experimental conditions where Cl2/I2 ≈ 110, the concentrations measured are (1.7±0.5)x1014/cm3.

Optical resonance cavities opt for the use of stable cavities. The optical cavity entry cross section is 30mmx500mm. The optical cavity light exit area cross section is 30mmx70mm. One way gain length is 500mm. Total reflector and output reflector distance is 900mm. Full reflectors are spherical reflectors. Curvature radii are of several types--5,10,20, and 30m. Rates of reflection are not less than 99.5%. Output reflectors are planar reflectors. The penetration rates are 1.4%, 2.0%, 2.2%, and 2.7%. Experimental light cavity pressures are approximately 133Pa.

Exhaust systems are composed of electromagnetic pumps with drawing powers of 2500L/s and mechanical pumps with drawing powers of 300L/s. During experiments, they are capable of guaranteeing that light cavity pressures are maintained at around 133Pa.

During experimental processes, use is made of thermometers and thermocouples to monitor $O_2(^1\Delta)$ generator solution temperatures and water vapor trap input and output temperatures. Use is made of infrared detection device PbS to monitor relative

$O_2(^1\Delta)$ concentrations. Use is made of electrical capacitance type M1151AP pressure guages to measure optical cavity pressures as well as chlorine gas Venturi tube prepressures. Using domestically produced M891 power meters, measurements were made of laser output powers.

Beam divergence angle measurements opt for the use of focal striation methods [9]. The focusing relfector f=1m. In

accordance with focal point location faculae dimensions D, beam divergence angles θ are directly solved for from the equation $\theta = D/f$.

3 EXPERIMENTAL RESULTS AND DISCUSSION

During experiments, there are alterations in output reflector coupling rates. Output powers show obvious changes. With a coupling rate of 1.4%, output power is 67-110W. For coupling rates of 2.0%, output powers are 166-244W. With coupling rates of 2.2%, output powers are 288-402W. And, for coupling rates of2.7%, output powers are 204-207W. From this, it can be seen that laser light cavity coupling rate optimum values are approximately 2.2%.

Laser beam divergence is the primary index of light beam quality. It directly influences the application range of the laser. The reason is that it will directly influence laser beam focusing properties and transmission efficiencies. Through a series of experiments, we obtained relationships between beam divergence angles and laser powers (Fig.3). From the Fig., it is possible to see that, following along with increases in power, beam divergence angles get larger. During the tests--through changing total reflector curvature radii and, at the same time, measuring beam divergence angles--it was discovered that enlarging cavity reflector curvature radii R, beam divergence angles got smaller. The reason was that curvature radii increases made basic mode beam waist dimensions get bigger. Certain high order modes were inhibited. However, the influence of R is limited. Experimental results are seen in Fig.4. Theoretically speaking, beam divergence angles are in inverse proportion to [L(R-L)]1/2 [10]. As far as increases in curvature radii R are concerned, although beam divergence angles get smaller, with regard to cavity adjustment precisions, however, requirements are high. Optical cavity stability is bad. In particular, with regard to low gain systems, they will make laser output powers drop.

Within a certain range, chlorine flow amounts will directly influence the size of laser output powers. When chlorine flow amounts are 38mmol/s, laser output powers reach 40.2W. If amounts of chlorine gas flow continue to increase, laser powers will, on the contrary, go down. This is because of deviations from the designed operating configuration of $O_2(^1\Delta)$ generators which were built for incomplete chlorine gas reactions.

Recently, a series of experiments were carried out on large dimension continuous wave oxygen-iodine chemical lasers with one way gain lengths of 100cm. Chlorine flow amounts were 50mmol/s.

Use was made of plano-spherical stable cavities. Total reflectors were R=20m spherical reflectors. When output planar reflector coupling rates were 4.8%, laser output powers reached 1Kw.

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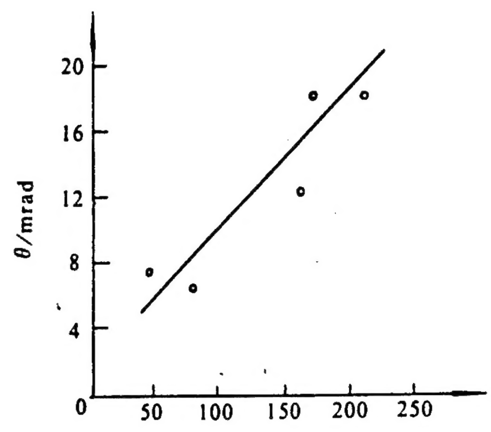

Fig.3 Relation of θ vs P

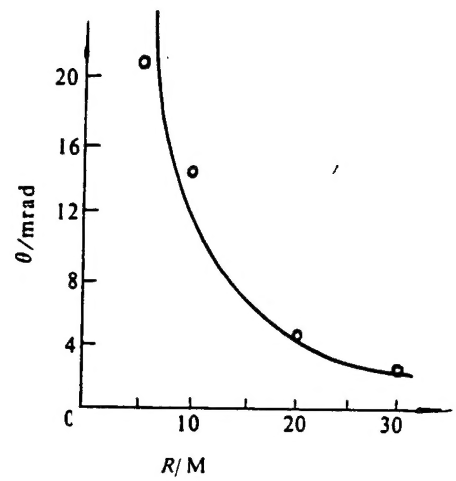

Fig.4 Relation θ vs R

Opting for the use of photolytic iodine lasers to act as detection light sources, measurements of optical cavity media small signal gain systems were 1.4x10-3/cm [11].

4 CONCLUSIONS

As far as oxygen-iodine chemical lasers making use of low concentration hydrogen peroxide (approximately 50%) are concerned, chlorine flow amounts are 38mmol/s. Maximum power reaches 402W. Optical cavity optimal coupling rate is 2.2%.

Minimum beam divergence angle is approximately 3mrad. When one way gain length is enlarged to 100cm, chlorine flow amount is 50mmol/s. Output powers reach 1kW. Gain media small signal gain systems are 1.4x10-3cm-1.

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REFERENCES

[1] Bachar J and Rosenwaks S. *Appl Phys Lett*, 1982, **41** :16.

[2] Shimizu K et al. *J Appl Phys*, 1991, **69** (1) :82.

[3] McDermott WE et al. *Appl Phys Lett*, 1978, **32** :469.

[4] Hiroo Fujii, Yoshida S et al. *J Appl Phys*, 1990 , **67**(9) :3948.

[5] Miller DJ et al. CLEO'82. Conference on Laser and Electro-Optics, Phoenix AZ (Optical Society of America, Washington, DC, 1982, 170.

[6] Military Space 1990 July 30.

[7] Vagin NP et al. Trudy FIAN 1989, **194** :114.

[8] 桑凤亭等. 用激光吸收法测量氧碘化学激光器光腔中碘的浓度. 中国科学院大连化学物理研究报告. 1992.

[9] Shimizu K et al. *J Appl Phys*, 1991, **69** (1):81.

[10] Nikio muro et al. Proceedings of LAMP'92 Naqaoka, June 1992.105.

[11] 桑凤亭等. 千瓦氧碘化学激光器光腔介质小信号增益系数的测量. 中国科学院大连化学物理研究所报告. 1993.

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